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ABSTRACT

The results of studies that have calculated projections of food deficits for less developed countries (LDC's) toward the year 2000 are compared. Included in the comparison are: (1) reports entitled "The Global 2000 Report to the President," "The Future of the World Economy," and "The Model of International Relations in Agriculture"; (2) work done at Iowa State University, the International Food Policy Research Institute, and the Food and Agriculture Organization of the United Nations; and (3) work sponsored by the Club of Rome. Almost without exception, these studies forsee a future for the food economies of LDC's characterized by rising deficits of consumption over production and/or increasing real food prices. These projects, most of which were initiated during the food crisis of 1973/74, are found to be at variance with observed trends in the post-war era and events occurring since the time they were conducted. A preponderance of attention on supply side factors, at the expense of a thorough investigation of transitory demand side influences, was characteristic of most of the studies. This incomplete diagnosis of the causes of the crisis contributed to a bias in the projections. (Author/RM)

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A Guide to Some Projections of LDC Food Security Toward the End of the Twentieth Century

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and
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Preface

This report was prepared as one of a series of studies undertaken at the University of Minnesota as part of a cooperative research program between the Hubert H. Humphrey Institute of Public Affairs and the Department of Agricultural and Applied Economics. The inquiry focuses on "The Future of the North American Granary": on the Granary's central role in the world food/feed picture and on the issues this responsibility presents for U.S. policy in several realms.

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A guide to some projections of LDC food security toward the end of the twentieth century*

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Summary

This paper compares the results of several studies that have calculated projections of food deficits for low income countries toward the year 2000. Included in the comparison is work done at Iowa State University (Blakeslee, et al, 1973), International Food Policy Research Institute (IFPRI, 1977), The Food and Agriculture Organization of the United Nations (FAO, 1981), The Global 2000 Report to the President (Barney, et al, 1980), The Future of the World Economy (Leontief, et al, 1977), the Model of International Relations in Agriculture (Linnemann, et al, 1979), as well as work undertaken under the sponsorship of the Club of Rome (Forrester, 1971; Meadows, et al, 1972; Mesarovic and Pestel, 1974; Herrera, et al, 1976). Almost without exception, these studies foresee a future for the food economies of LDC's characterized by rising deficits of consumption over production and/or increasing real food prices. These projections are found to be at variance with observed trends in the post-war era, and events occurring since the time the studies were conducted. Many of the available food deficit projection exercises were initiated in the midst of the food crisis of 1973/74. It is our view that a preponderance of attention on supply side factors, at the expense of a thorough investigation of transitory demand side influences, was characteristic of most of the studies reviewed and that this incomplete diagnosis of the causes of the crisis contributed to a bias in the projections.

* This study was conducted as a joint project of the Department of Agricultural and Applied Economics and the Hubert H. Humphrey Institute of Public Affairs of the University of Minnesota.

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1. Introduction

The years since World War II have witnessed a remarkable increase in the level of world food production. They have also witnessed sharp swings in both popular and professional concern about the ability of the global community, and of the developing countries in particular, to meet the food demands generated by growth in population and income.

Perspectives shifted from a sense of impending catastrophy engendered by the food crisis of the mid-1960's to euphoria about the food production potential opened up by the green revolution of the late 1960's. This was followed by a new wave of "food pessimism" in the mid-1970's. Particular attention was focused on the ability of the less developed market economies to produce food at a level adequate to meet expected domestic demand. The outlook generated by these studies was generally pessimistic, with consumption outpacing production anticipated for many third world countries. The general tone of these reports was that factors such as resource depletion, climatic shift, risks from extensive monoculture agriculture and the exhaustion of the "technology reservoir" were leading to a period of increasingly actue shortages of food and secularly rising real prices for food commodities.

The fundamental question that these studies attempted to assess was whether the early 1970's constituted a temporary aberration from favorable long trends or if a new trend characterized by growing food deficits in the developing countries was in the offing. The answer offered by each of the studies reviewed below suggested a sharp break with the past. The projections tended to reinforce a perception that the forces that guided the evolution of the world food system in the post-war era had experienced a fundamental shift by the mid-1970's and that shift would have grave consequences in the absence of concerted international development assistance.

The purpose of this paper is to compare and contrast a set of these food system projection studies with the objective of identifying features common to each study that may have contributed to the uniform pessimism exhibited by the group. With the benefit of hindsight, it appears that these studies failed to accurately diagnose the underlying phenomena that generated the chaotic behavior of primary commodity markets in the 1970's. As a result they have failed to track very well against emerging developments in the world food economy.

2. Background

In this section, we review some of the conditions in the world food economy prevailing in the early 1970's in light of historical experience and of developments of the last decade.

The three decades since 1950 have witnessed a steady improvement in the world's capacity to produce food, measured either in absolute or per caput terms. Total food production has doubled in 30 years, implying an average annual compound growth rate of about 2.5% per annum. What is perhaps most impressive is that this growth has been strongest in the LDC's, where an average annual growth rate of almost 3% per annum was achieved, and in the USSR and the Eastern European centrally planned economies, where food output grew at 2.8% per annum.

Measured on a per caput basis, the gains have been less dramatic but still impressive. At a global level, food output per caput increased at an average annual rate of 0.71%. In the LDC's, the corresponding figure was 0.55%, but this single number encompasses a growth rate for East Asia of 1.46% per annum, and a contraction of 0.44% annually in food production per caput in Africa.[1/] Somewhat surprisingly, food availability per person increased at 1.75% per annum in the USSR and Eastern European centrally planned economies. This result must be interpreted in light of the very

low base for the USSR in the early 1950's. Also, food output has become more variable in the USSR during the 1970's and has declined since 1978. Tables 1 and 2 report growth rates of food production and food production per caput by regions from 1951 to 1981.

Not only has food production generally outpaced population growth globally in the postwar era, evidence suggests that supply shifts have exceeded demand shifts. World Bank records of constant (1979) U.S. dollar prices of internationally traded foodstuffs show a downward trend for rice, sorghum, maize and wheat (World Bank, 1981). Recently, Martin and Brokken (Martin and Brokken, 1982) have published a series of real prices for wheat and corn in the United States, for the years 1866-1981 (Figure A-1). These data show a significant downward trend for wheat, and no trend for corn. Furthermore, the commodity price boom of 1973/74 is rather unspectacular when compared to earlier fluctuations in these real price series. The trend for grain prices may not be strong in some instances and price variability increased in the 1970's, but the available data certainly do not support the hypothesis of increasing real food prices from 1951-1981.

The tone of this discussion, of course, begs the question as to why concern about the ability of food output to meet anticipated demand has intensified during the last decade. A prudent economist might choose to leave that question to the social psychologist or the historian. Nevertheless, some reasons for heightened food security concerns can be identified. First, while the post-war trend in real food prices may be downward, price variability in output and input prices increased sharply in the 1970's. Table 3 records that after a relatively stable decade from 1960-69, world agricultural commodity prices became highly volatile in the 1970's. Much of this price movement consisted of sharp increases in constant dollar prices from

Table 1. Average Annual Percentage Change in Total Food Production, 1951-1981.[1,2]

Country/Region	1951-53 to 1959-61	1959-61 to 1969-71	1969-71 to 1979-81	1951-53 to 1979-81	1959-61 to 1979-81
United States	2.45	2.06	2.37	2.28	2.21
Canada	-0.71	3.17	2.12	1.67	2.64
Japan	4.02	0.10	-0.17	1.11	-0.04
Republic of South Africa	3.66	3.74	3.18	3.51	3.46
Oceania	2.94	3.48	1.52	2.62	2.50
Western Europe	2.67	2.39	1.90	2.29	2.14
Developed World	2.64	2.09	1.87	2.17	1.98
South and Central America	3.11	3.78	3.66	3.55	3.72
East Asia[3] (Ex Japan)	3.80	3.52	4.13	3.81	3.82
South Asia[4]	3.10	2.65	2.07	2.57	2.36
Middle East[5]	3.23	2.86	3.61	3.23	3.25
Africa (Ex Rep. So. Africa)	2.39	2.42	1.78	2.18	2.10
Less Developed World	2.99	2.96	2.79	2.91	2.88
Eastern Europe	3.19	2.13	2.15	2.44	2.14
USSR	5.62	3.30	1.05	3.14	2.17
China[6]	-0.05*	5.34	2.5 †	2.41*†	4.06†
Centrally Planned[7]	4.66	2.85	1.50	2.88	2.17
World[7]	3.22	2.56	2.01	2.55	2.28

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Table 1 (continued)

Notes:

1. Authors' calculations based on Appendix Tables A-1 and A-2.
2. Growth rates were computed as $1 + r = e^{\left(\frac{\ln \bar{y}_{t1} - \ln \bar{y}_{t0}}{t^1 - t^0}\right)}$ where $\bar{y}$ represents a 3-year average.
3. Burma, Indonesia, Republic of Korea, West Malaysia, Philippines, Taiwan, Thailand.
4. Afghanistan, Bangladesh, Sri Lanka, India, Pakistan.
5. Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey.
6. Based on author's calculations using estimates of Tang and Stone.
7. Excludes People's Republic of China.

* Series begins in 1952. Agricultural Output reported for 1959-61 was considerably below the preceding and ensuing years.

† Data available to 1976-77 only.

Table 2. Average Annual Percentage Change in Food Production Per Caput, 1951-1981.[1,2]

Country/Region	1951-53 to 1959-61	1959-61 to 1969-71	1969-71 to 1979-81	1951-53 to 1979-81	1959-61 to 1979-81
United States	0.75	0.73	1.56	1.03	1.14
Canada	-3.36	1.44	0.87	-0.16	1.15
Japan	2.34	-0.89	-1.34	-0.14	-1.12
Republic of South Africa	1.01	1.03	1.47	1.18	1.23
Oceania	0.64	1.52	0	0.72	0.76
Western Europe	1.85	1.59	1.46	1.62	1.53
Developed World	1.47	0.98	1.05	1.15	1.01
South and Central America	0.28	1.03	1.14	0.85	1.08
East Asia[3] (Ex Japan)	1.47	0.98	1.92	1.46	1.45
South Asia[4]	1.28	0.41	-0.13	0.46	0.14
Middle East[5]	0.13	0.10	0.89	0.50	0.50
Africa (Ex Rep. So. Africa)	0.04	-0.10	-1.16	-0.44	-0.63
Less Developed World	0.91	0.47	0.33	0.55	0.40
Eastern Europe	1.47	2.07	1.11	1.56	1.59
USSR	4.64	1.41	0.16	1.87	0.78
China[6]	-2.72*	2.92	0.53†	0.46*†	1.94†
Centrally Planned[7]	3.07	1.80	0.65	1.75	1.22
World[7]	1.42	0.62	0.23	0.71	0.42

Notes: See Table 1.

Table 3. Price Variability of Selected Traded Agricultural Commodities, 1950-1980[1]

Commodity	Coefficient of Variation (%)		
	1950-59	1960-69	1970-80
Rice[2]	11.9	17.3	39.6
Maize[3]	22.1	8.7	24.5
Wheat[4]	14.5	3.3	31.9
Sugar[5]	27.34	64.1	63.4
Soybeans[6]	16.6	6.9	26.4

1 Authors' calculations based on data from Commodity Trade and Price Trends, distributed for the World Bank by Johns Hopkins University Press, August 1981.

2 Thai rice, 5% broken, milled, f.o.b. Bangkok, 1980 constant $ U.S.

3 United States, No. 2 yellow, f.o.b. Gulf Ports, 1980 constant $ U.S.

4 Canadian, No. 1 Western Red Spring, basis in store, Thunder Bay, 1980 constant $ U.S.

5 1950-1960 refers to New York, World Contract No. 4, f.a.s. Cuba. After 1960 International Sugar Council World daily price, f.o.b. and stowed, Caribbean ports, 1980 constant $ U.S.

6 U.S. No. 2 Bulk, c.i.f. Rotterdam, constant 1980 $ U.S.

1970 to 1975 followed by a decline in late 1975 and continued instability thereafter. From the vantage point of the mid-1970's, therefore, it was hard to resist the perception that real food prices had begun a new upward trend.

Secondly, price variability of raw materials for agriculture increased dramatically. Table 4 reports a sharp increase in the coefficient of variation for petroleum, phosphate rock and urea prices from the 1960's to the 1970's. Again, the pattern is a sharp increase in prices in the early 1970's with larger than historical shocks thereafter. Price variability on the input side appeared to threaten the advances achieved by the fertilizer intensive green revolution technology.

It is often argued that a collapse in the supply of grain, both in terms of reduced production and decreased stocks, was a prime factor in the food price explosion of 1973/74. Occasionally, it is argued that trade flows were choked off by these supply side shocks. The data of Table 5 would suggest another explanation. While it is true that total cereal production fell between 1971/72 and 1972/73, and stocks declined, the diminution of stocks was not unprecedented, and both production and stocks recovered quickly. What is important to note is that the increase in utilization of grain between 1971/72 and 1972/73 was of approximately the same magnitude as the decrease in supply. In other words, one must seek a more general explanation than the supply side rationale to account for the food price movements of major concern for policy makers in the 1970's.

Table 4. Price Variability of Selected Agricultural Raw Materials 1950-1980[1]

Commodity	Coefficient of Variation (%) 1950-59	1960-69	1970-80
Petroleum[2]	10.0	7.1	54.6
Phosphate Rock[3]	7.9*	7.0	54.2
Potassium Chloride[4]	7.5*	12.6	18.6
Urea[5]	--	17.6**	55.4

Notes:

1 See Table 3, note 1 for source.

2 Saudi Arabian (Realized Price), Light Crude, 34°-34.9° API gravity, f.o.b. Ras Tanvra, constant 1980 $ U.S.

3 Moroccan, 72% BPL, f.o.b. Casablanca. Prior to December 1975, 75% BPL constant 1980 $ U.S.

4 Canadian muriate of potash, f.o.b. Vancouver, constant 1980 $ U.S.

5 Any origin, f.o.b. Europe.

* Based on 1955-59 only.

** Based on 1963-69 only.

Table 5. World Total Grain[1] Production, Utilization, Trade and Stocks, 1960/61 to 1982/83[2] (million metric tons)

Year	Production	Utilization	World Trade[3]	Stocks[4]
1960/61	844.5	831.1	72.5	198.0
1961/62	804.8	832.1	83.5	170.2
1962/63	865.4	863.2	82.3	172.5
1963/64	869.1	868.7	97.8	172.9
1964/65	921.8	917.6	95.0	177.1
1965/66	920.2	954.0	110.7	143.3
1966/67	1004.9	978.4	104.0	169.8
1967/68	1036.8	1016.2	96.9	190.4
1968/69	1076.5	1045.2	88.4	221.7
1969/70	1086.9	1102.4	96.8	206.2
1970/71	1100.6	1141.8	109.7	165.0
1971/72	1193.2	1175.1	109.8	183.7
1972/73	1160.9	1202.6	134.3	142.4
1973/74	1266.6	1261.5	142.1	147.0
1974/75	1211.7	1225.9	135.6	132.8
1975/76	1242.0	1235.0	151.9	139.7
1976/77	1360.3	1307.4	156.1	193.5
1977/78	1333.2	1332.9	166.4	193.4
1978/79	1459.7	1432.6	173.8	220.2
1979/80	1418.4	1441.9	109.6	196.7
1980/81	1435.3	1451.8	211.7	180.3
1981/82[5]	1502.7	1468.7	214.1	214.3
1982/83[6]	1485.8	1484.1	219.3	215.9

Notes:

1 Wheat, Course Grains, and Rice.

2 Foreign Agricultural Circular, Grains, USDA, Foreign Agricultural Service, Washington, D.C., July 15, 1982, p. 27.

3 Excludes intra-EC trade.

4 For countries for which stocks data are not available (excluding USSR) utilization includes an estimate of stock adjustments. Stocks are estimated by aggregating data of differing marketing years and are not to be taken as estimates of world stocks at a point in time.

5 Preliminary.

6 Projection.

3. On the Geneology of Global Models

The decade which began in 1970 witnessed a confluence of intellectual developments and world events which fostered the first formal attempts to create models of the world as an integrated system. A catalyist to these efforts was a dramatic increase in both the accessibility to large scale digital computers and in the human capital required to use these devices by professionals with social science interests. Suddenly, it was possible to build and manipulate analogues of complex interrelated social phenomena that were almost beyond comprehension only ten years earlier. Accompanying this new analytical capacity was a growing perception that problematic issues of economic and environmental policy were fundamentally international in scope. Several research programs were initiated which attempted to quantify and stimulate the behavior of the world food system.

3.1 Global Systems Analysis

The earliest and most fecund of these programs was initiated at MIT by J. Forrester (Forrester, 1971; Meadows, et al, 1972) under the sponsorship of the Club of Rome. These initial efforts produced the World 1, World 2 and World 3 models, and precipitated discussion which subsequently led to the creation of the World Integrated Model (Mesarovic and Pestel, 1974), the Latin American World Model (Herrera, et al, 1976) and the Model of International Relations in Agriculture (MOIRA) (Linnemann, et al, 1979). Also, the later work of the International Institute for Applied Systems Analysis (Parikh and Rabar (eds.), 1981) could be seen as an attempt to further develop systems simulation procedures for the world agricultural system. It is clear from the early writing of Forrester that a primary motivation for his research arose from the apparent conflict between exponential growth rates of population, economic activity and resource depletion

in the post-war era with the finite resource capacity of the planet. Extrapolation of exponential trends foreshadowed worldwide catastrophe. A theme throughout the related literature has been the search for a "Global Sustainable Equilibrium" or steady state, and for a set of policies that would yield such an outcome.[2/]

In response to critics, modifications were embodied in each successive round of development of this sequence of models. Nordhaus (Nordhaus, 1974) criticized early work by Forrester on three counts. First, the functional relationships in World Dynamics were purely conjectural. In his words, "Not a single relationship or variable is drawn from actual data or empirical studies" (emphasis original). As an example, population growth was postulated as a universally increasing function of affluence, which Nordhaus contended was blatantly contrary to available evidence.[3/]

Secondly, economic analysis was conspicuously absent from the model's structure. No price system or incentive structure was available to guide resource use in response to changing patterns of scarcity. Substitution among factors was precluded. Technological change was assumed away.

Finally, contrary to the assurances of Meadows, et al, Nordhaus and others found the prediction of global catastrophe of the Malthusian sort not to be robust under changes in the values of assumed parameters or of model structure.

In a subsequent round in the development of global projection models, Mesarovic and Pestel created the World Integrated Model. The Mesarovic and Pestel work embodies at least three important innovations. First, the model is much less aggregative than the Limits to Growth work. Rather than amalgamating variables into global measures, regional aggregates are constructed. In general, the feedback mechanisms and interdependencies among variables are more complex than those of the World 1 - World 3 models.

Secondly, more attention was paid to the empirical validation of relationships postulated in the model. The principal investigators in the World Integrated Model went to great lengths to emphasize that their results were based on "real numbers."

Thirdly, the economic content of the World Integrated Model is considerably more sophisticated than that of its predecessors. On the production side, production functions were specified for the model's regions. Capital was accumulated endogenously and labor force participation was linked to the demographic profiles. Input-output sub-models were developed for several regions. On the consumption side, demand for agricultural products was linked to income per caput and a price system created incentives to direct inter-sectoral investment.

While the World Integrated Model represents an escalation of the complexity of global models, its predictions have much in common with Limits to Growth work. The conclusion again is that the existing path of global social and economic development is in a collision course with inevitable crisis.

The Latin American World Model (Herrera, et al, 1976) emerged in response to the work of Meadows, et al, and the discussions of the Club of Rome. It should perhaps be seen, however, as a reaction to rather than an extension of the Limits to Growth analysis. The creators of the Latin American World Model were critical of the perception that bio-physical and ecological constraints were the preeminent obstacles to the achievement of global prosperity. For example, the model assumed a constant production cost for raw materials and energy for the period 1960-2060, and assumed that existing social institutions were adequate to safeguard environmental quality. Their alternative formulation stressed the role of socioeconomic problems and in particular the effects of inequitable distribution of political and economic power in

the emergence of global crises. The model was essentially a global dynamic optimization model where the optimization problem consisted of using the world's resources to satisfy a basic human needs criterion that led to the maximization of life expectancy at birth. Thus, the model is less of a forecast of likely outcomes than a blueprint of policies and programs dedicated to the achievement of the stipulated goal. The principal result of the model is that, given the set of optimal policies generated by the solution, a standard of living consistent with the satisfaction of basic human needs could be attained globally within one generation. Furthermore, such an enhancement of material welfare was found to depress population growth rates, avoiding the "overshoot and collapse" syndrome of the World models and the World Integrated Model. Consistent with the beliefs that motivated the analysis, physical and ecological barriers do not effectively constrain the growth path under optimal policies, but political and social obstacles to the redistributive nature of the policy prescriptions are important.

An interesting aside is that conventional development assistance, even at a level above the U.N. development decade recommendations, was not found to make an appreciable contribution to the global development path.

A contrasting approach was used in the research program initiated in 1973 by W. Leontief (Leontief, 1977) on behalf of the United Nations. Leontief and his associates developed global Input/Output models to examine the targets of the International Development Strategy adapted by the U.N. in 1970, in terms of its impact on environmental quality and its resource requirements. The model was used to test the feasibility of the targets set by the U.N. in terms of non-renewable resource requirements.

3.2 Sectoral Models of Agriculture

The Model of International Relations in Agriculture (MOIRA) (Linnemann, et al, 1979) and the Grain, Oil and Livestock (GOL) model of the USDA can be

interpreted as sectoral models of agriculture. This designation arises from the fact that both treat economic growth and price movements outside of agriculture as largely exogenous and also environmental quality issues are less prominent than in the Global Systems Analysis models.

The MOIRA model attempts to provide a framework for understanding the causal relations embodied in the world food system and also to facilitate the analysis of the impact of policy measures relating to the world food situation. The study, undertaken by a team of Dutch agronomists and economists, grew out of the work of the Club of Rome, and was initiated in 1972-73. The final report was published in 1979, but the work was largely completed by the end of 1977.

The model consists of 106 regional or national sub-models, each with a food production and food consumption component, with international trade linkages connecting the sub-models. Economic analysis is much more prominent than in the models built in the "world dynamics" tradition. Production is a function of land, labor, capital and fertilizer inputs. Consumption is a function both of real income and its distribution. Some attempt is made to incorporate public regulation of domestic food systems.

The GOL model was developed in 1974 by the USDA in response to the dramatic instability of primary commodity prices that emerged in 1972/73. It is essentially a static partial equilibrium model of world agricultural commodity markets that incorporates trade linkages. The GOL model was used to generate the food and agricultural projections undertaken for the Global 2000 Report to the President (Barney, et al, 1980).

The GOL model is a large (930 equation) econometric model estimated on data from 1950-1975. Details of the model are documented in USDA publications (Regier, 1978; Rojko, et al, 1978). The model takes GDP and population

growth as exogenous and simulates resource use competition, commodity substitution and fertilizer derived demand for the given external conditions. An attempt is made to reflect institutional factors, policy constraints and changes in consumer preferences in the specification of the model.

3.3 Modelling Strategies

To date, two broad options have been available to practitioners of global modelling. The first approach is to specify a set of "equations of motion" for an interdependent set of variables, which are started from some set of initial conditions and allowed to jointly evolve through time. Forrester's World models, the World Integrated Model, Leontief's Global Input-Output model and the Latin American World Model are of this general type, although this is a highly heterogeneous set. An important feature of this approach is its ability to economize on the use of exogenous factors. If the modeler is willing and able to specify an equation of motion for a variable, that variable becomes "endogenized." Sensitivity analysis is conducted primarily through altering the structure of the set of equations of motion. The number of conceivable scenarios is an exponential function of the number of equations and the numbers of parameters subject to variation.

The second approach is largely based on standard econometric techniques. A system of simultaneous equations is estimated using a data set which includes time series observations on a set of variables assumed exogenous to the system. Typically a system consists of a number of partial equilibrium market models with trade linkages of various types. Projections are derived by specifying alternative time paths for the set of exogenous variables, substituting these time paths into the system of estimated equations and solving the system for the endogenous variables at particular points in time. In this case, the number of conceivable scenarios is an exponential function

of the number of exogenous variables and the number of assumed time paths per exogenous variable. The GOL model and MOIRA use this approach.

Although the history of global models has been a brief one, the rate of "technological change" has been rapid. The movement has been from simple models based on intuitive plausibility to complex structures with a heavy emphasis on validation. Longer construction and handling time have accompanied this progression.

Models have become evolving entities, subject to frequent modification and revision, and often able to be run with sub-components dormant or deleted. As a consequence, it has become more difficult to "describe" a model, except as a snapshot profile at a point in time. An undesirable side effect of complexity is that it has become increasingly difficult to report or even to understand the linkage between the structure of a model or its assumptions and the results or projections of a particular analysis. As the number of exogenous variables and the number of path assumptions per exogenous variable increase, the number of scenarios rises as an exponential function and the set of cases to examine quickly becomes unwieldy. For example, 4 exogenous variables each with 3 alternative time paths produces 64 scenarios. Earlier models by Forrester and Mesarovic and Pestel avoided this complexity by making models where few variables were exogenous.

Global modellers have become more circumspect in their claims over the past dozen years. It was common for earlier studies to speak in terms of predictions, whereas more recently results are seen as conditional projections of future events. The study team reporting on MOIRA describes its work as follows:

> Suffice in here to stress that MOIRA should not be seen as a forecasting or prediction model, but as a simulation model useful for the analysis of alternative policies (Linnemann, et al, 1979, p. 7).

This shift of emphasis needs to be seen as something more than hedging by researchers. A fundamental problem of global forecasting is that social self-regulatory feedback relationships are complex, not well understood by disciplinary specialists, and subject to intervention in the form of policies. Under these circumstances it is conceivable that a "perfect" forecast could prove to be self-defeating, in the sense of self-falsifying, if it became an important input to policy formulation.

Finally, it is worth noting that some have accused this evolutionary process as being biased by "economist imperialism." Hans Linnemann, project leader of the MOIRA team (and an economist) expressed the problem in the following way.

> In all fairness it should be added that in the birth process of MOIRA on occasions the economists have forced the contributions of agronomists into a bodice that, in the opinion of the latter, came pretty close to a strait jacket. The reader whose background is in the agricultural sciences should accuse the economists of our group, rather than the agronomists, whenever he finds that the insights obtained in his discipline are made use of in too rough a manner (Linnemann, et al, 1979, pp. ix, x).

Even in the interdisciplinary framework that has characterized most model development, this result is not surprising. The technology of social model building is more familiar to economists, than other disciplines involved in these studies, and a large stock of experience and literature exists to draw on. It is understandable, therefore, that the economic content of more recent models is considerably more sophisticated than earlier work and that in many cases this has led to an effective displacement of other disciplines. This is not to say that the net effect of economists has been negative. It is the view of the authors that, by emphasizing the role of resource substitution in production and commodity substitution in consumption, and the link between scarcity and prices, economists have made an important contribution toward placing these projection exercises on a firmer footing.

4. Food Balance Projections: Selected Models and Results

This section reviews recent studies which have generated projections of food production, consumption and deficits in the LDC's toward the end of the twentieth century. The purpose of this discussion is to compare the projected magnitudes of those food deficits, and to relate contrasts in projections to variations in model structure and data inputs.

The Global and Sectoral Models discussed above are compared where comparisons are feasible. In addition, three trend projection models developed by Iowa State University (Blakeslee, et al, 1973), the International Food Policy Research Institute (IFPRI, 1977) and the FAO (FAO, 1981) are discussed. These trend based models are reminiscent of an earlier generation of projections discussed by Sanders and Hoyt (Sanders and Hoyt, 1970).

Table 6 summarizes the recent performance of food production vis-a-vis consumption in the LDC's since 1960, and also reports projected magnitudes of the deficits anticipated by some of the studies to be compared.

4.1 The Trend Projection Models

The three trend projection models have a great deal in common with respect to methodology. In each study, consumption per caput is projected as an increasing function of income per caput. Hence, to implement the approach, estimates of income per caput. population and income elasticity are necessary, usually at a national level.

Typically, the UN medium variant is used as the population estimate. Production is extrapolated from trends using various least squares approaches, and the projected deficit is the difference between consumption and production. Each of the three trend projection studies neglect the effect of price movements on food consumption or production. The resulting deficit measures should thus be interpreted as excess demand at constant real prices for food.

Table 6. Total LDC Cereal Production, Disappearance and Deficits - Actual[1] and Projected, 1960-2000 (million metric tons)

Year	Production	Disappearance	Deficit
1960-63	233.5	244.2	13.4
1964-67	262.0	262.2	10.5
1969-72	307.2	324.5	18.4
1973-74	324.1	351.3	27.4
1974-75	313.8	348.9	35.0
1975-76	348.1	368.7	31.5
1976-77	361.1	379.0	24.0
1977-78	358.7	387.9	26.3
1978-79	390.2	432.5	41.3
1979-80	372.0	434.5	56.4
1980-81	401.5	453.8	55.0
Iowa State[2]			
1985			
L	366.7	482.2	115.5
H	371.1	482.2	111.1
2000			
L	440.5	696.2	255.7
H	401.1	696.2	235.1
IFPRI[3]			
1990			
At 1975 Per Caput Consumption	598.6	618.8	20.2
Dietary Energy Requirements	598.6	707.8	109.2
Low Income Growth	598.6	682.2	83.6
High Income Growth	598.6	705.9	107.3
FAO[4]			
1990			
Trend	518.0	590.0	72.0
A	569.0	626.0	57.0
B	538.0	605.0	67.0
2000			
Trend	636.0	768.0	132.0
A	786.0	850.0	64.0
B	696.0	801.0	105.0

Table 6 (continued)

Year	Production	Disappearance	Deficit
Global 2000[5]			
1985			
I	471.7-490.7	526.0-522.3	54.3-31.6
II	485.3	529.7	44.4
III	470.5	506.3	35.8
2000			
I	735.0-740.6	789.8-772.4	54.8-31.8
II	757.0	790.4	33.4
III	745.3	799.4	54.1
Leontief[6]			
1980		926.8	
1990		1475.3	
2000		2327.7	

Notes:

1 USDA, World Agricultural Situation, various issues.

2 L. L. Blakeslee, et al, World Food Production, Demand and Trade, Iowa State University Press, Ames, Iowa, 1973.

3 "Food Needs of Developing Countries: Projections of Production and Consumption to 1990," Research Report #3, IFPRI, December 1977. Data reported is in Cereal Equivalents. IFPRI is in the process of updating these projections, but results have not yet been published.

4 Agriculture Toward 2000, FAO, Rome, 1981.

5 Barney, G.O., et al, The Global 2000 Report to the President, Vol. 1, 2, 3, Council on Environmental Quality and the Department of State, Washington, D.C., 1980.

6 W. Leontief, et al, The Future of the World Economy, Oxford University Press, New York, 1977.

A subset of the Iowa State projections is reported in Table 6. The estimates are for total cereal consumption and production for 53 low income countries. Income per caput is projected at trend and the UN medium variant is used to forecast population. The L and H denote Low and High levels of expansion of crop area.

The IFPRI projections are for 82 developing market economies for the year 1990. Four consumption projections are made. The first represents the effect of anticipated population growth alone, leaving per caput consumption at the 1975 level. The second is based on the FAO's minimum caloric intake estimates. The final two demand projections are based on the standard approach described above. Under high income growth, the 1960-74 growth rates of GNP per caput were assumed for non-oil exporting countries, with a minimum rate of 1.5 percent per year. For major oil exporting countries, extension of the more rapid rates of 1965-74 generally was assumed, with a minimum of 4 percent per year. The low income growth rate was assumed to be one-fourth slower than the high income assumption, with a minimum of 0.5 percent per year. This scenario is intended to represent an extension of relatively slow growth in non-OPEC LDC's in recent years.

Production includes cereals as well as the cereal equivalent of groundnuts, pulses and root crops where the latter foodstuffs are important staples. Output is projected from a least squares trend fitted to 1960-75 for cereals and 1961-74 for pulses, groundnuts and root crops.

The FAO has published projected food deficits for 90 LDC's for the years 1990 and 2000. The demand model is not explicitly reported. However, the growth rate of demand is reported and is taken to be the product of income elasticity and the income growth rate, although only the product is reported.

Output is projected as a growth function of output in the base year. Three growth rates are studied. The first is a trend projection. A normative scenario, identified as "A", describes conditions considered to be consistent with widespread improvement in food availability by the end of the century. Scenario B is a projection intermediate to Trend and A.

4.2 The Global 2000 Model

One of the limitations of the methodology employed in the Iowa State, IFPRI and FAO studies is the inability of the analytical framework to accommodate price determination and its effect on projected deficits. Projections of food balance for 1985 and 2000 incorporated in the Global 2000 Report do reflect such price effects. Food and agriculture projections incorporated in the report are based on simulations using the Grain Oilseed and Livestock (GOL) model of the USDA. In the GOL framework, food deficits should be interpreted as net trade position in cereals at the prevailing world price, adjusted for trade restrictions.

Simulations were constructed for three scenarios, designated I, II and III. Scenario I is considered to be a trend or "baseline" projection in terms of the underlying assumed growth rates of population, GDP per caput, crop yields and weather. Two sets of results are reported for this scenario, the first indicative of constant real prices of energy and the second representing a doubling of energy prices by the year 2000.

Scenario II is the optimistic projection based on lower population growth rates and higher GDP per caput growth. Crop yields are projected at one standard error above trend, to reflect favorable weather, and energy prices are held constant in real terms.

Scenario III is the pessimistic alternative, with high population growth rates, low growth in GDP p.c., crop yields at 1 standard error below trend and energy prices doubling by 2000.

In each scenario, food production in LDC's as a group grows faster than the corresponding Global aggregate. On a per caput basis, however, the projections are less favorable, showing only modest gains in I and II, and deterioration under alternative III, in LDC food production.

4.3 Leontief's Input/Output Model

An Input/Output model was used as a technique of resource and environmental accounting to assess the feasibility of the U.N.'s International Development Strategy. Leontief's model therefore, works backwards from growth targets to implied sectoral output growth rates and resource use. The International Development Strategy establishes a GDP growth target of 6% per annum for LDC's. With an assumed population growth of 2.5% per annum, this yields a 3.5% per year rate of growth in GDP per caput. Similarly, a growth target for agricultural output is set, as opposed to projected from trend or a formal model. Such a procedure would render food deficit projections meaningless, and in fact such deficits are not reported. Food demand is projected, however, as shown in Table 6. This figure can be interpreted as the levels of food demand that would be generated for target income and agricultural output rates and the U.N. medium variant population projections. Grain disappearance estimates computed by Leontief include feed grains, however, and are therefore not directly comparable with the other elements of Table 6.

4.4 Club of Rome Models

Several investigations under the auspices of the Club of Rome have produced projections of world food balances. In fact, it could be argued that these studies and reactions to them were an important impetus to the study of projection models by other agencies. One limitation of the Club of Rome studies is their focus on digestible protein as opposed to caloric intake. This makes comparisons with the models described above quite difficult.

Forrester performed a simple food adequacy projection in the context of the world models. In the scenarios where the effects of resource depletion and pollution are held in abeyance, population reaches an upper limit of 10.8 billion constrained only by the world's capacity to produce capital and by the simple production function for agriculture. Although this early work, and subsequent simulations by Meadows, et al, attracted considerable attention, the level of aggregation, the simplicity of model structure, and absence of validation seriously undermines the credibility and relevance of the results.

The World Integrated Model reported by Mesarovic and Pestel contained a food sector sub-component. This model was used to generate projections of the world food situation for the years 1975-2025, the results of which are presented by Clapham, et al (Clapham, et al, 1974a, 1974b). The model is divided into 10 regions. Severe food deficits are projected for South Asia, reaching a level of 20 million tons of protein equivalent per annum by the year 2000. Details of the underlying assumptions which generated this result are not reported.

4.5 Model of International Relations in Agriculture (MOIRA)

MOIRA was constructed by an interdisciplinary team at the Free University of Amsterdam between 1973 and 1977. The focal point of the study was the world's capacity to meet food production needs in the year 2010. That particular date was selected because the world's population was expected to be twice the 1970 level by that time.

Contrary to the earlier work sponsored by the Club of Rome, natural and resource constraints were not found to be the predominating factor in world food supply. The MOIRA team estimated that available global resources and technology are capable of producing 30 times the level of food output

achieved on average in the three years centered on 1965 (Linnemann, et al, 1979, Chapter 2; DeHoogh, et al, 1976).

Briefly, supply is modeled for each of 106 producing regions as a consequence of sectoral value added maximization given resources, input prices and a production function. Consumption is disaggregated into 12 income classes for each of the 106 regions and countries and is specified as a function of income per caput and food price levels. So called "Consumable Protein" was chosen as the unit of measurement for output, defined as:

> "the amount of protein present in all vegetal agricultural products which are edible for the human being, plus the proteins in animal products for as far as these are generated by vegetal cattlefood which is not suitable for human consumption" (DeHoogh, et al, 1976).

Governments are assumed to intervene at their borders with some but not complete success to achieve an income parity target between domestic agricultural and non-agricultural sectors. World prices are established iteratively by acting on domestic incomes and price levels until supply and consumption plus stockpiling are matched. Variables taken as exogenous are GDP growth outside agriculture, population, income distribution, and prices of agricultural inputs. Table 7 reports the evolution of MOIRA's key endogenous variables under alternate growth assumptions. High growth corresponds to the basic scenarios of Leontief and moderate growth is approximately one-half of the high growth rate. High rates of income growth are associated with higher food output than moderate growth. Demand still outpaces supply under high growth, however, as evidenced by increasing world prices as compared to decreasing world prices under moderate growth.

In the slower growth scenario, lower food prices are not sufficient to reduce the magnitude of the hunger problem, as the burden of lower rates of food output fall primarily on poor rural populations. The price series

Table 7. Selected Projections of the Model of International Relations in Agriculture (MOIRA)

	High Income Growth						Moderate Income Growth					
	Unchanged policy: standard run						Unchanged policy: standard run					
	1966	1975	1980	1990	2000	2009	1966	1975	1980	1990	2000	2009
TOTAL AGRICULTURAL PRODUCTION (10^8 kg cons. prot.)												
World	1943	2495	2970	4094	5340	6530	1943	2491	2860	3452	4055	4796
Developed countries	743	910	1067	1517	1896	2194	743	909	1047	1221	1409	1559
North America	403	497	580	855	1009	1151	403	497	566	639	709	771
European Community	147	182	218	297	377	434	147	182	216	252	292	333
Developing countries	599	749	941	1237	1774	2344	599	749	918	1118	1352	1721
Latin America	181	241	297	434	631	905	181	241	296	430	604	848
Tropical Africa	66	82	96	145	208	297	66	82	96	109	142	169
Middle East	58	72	96	128	220	287	53	72	96	113	174	204
Southern Asia	265	321	409	467	624	736	265	321	386	407	351	395
FOOD CONSUMPTION PER CAPUT (kg cons. prot.)												
World	46	50	53	61	68	73	46	50	51	52	52	53
Developed countries	86	102	110	130	147	160	86	101	106	113	120	125
North America	107	121	129	148	163	173	107	120	123	130	136	140
European Community	90	103	108	126	141	153	90	103	107	114	120	126
Developing countries	30	30	33	37	43	48	30	30	32	31	30	31
Latin America	43	48	52	63	76	89	43	47	49	51	53	55
Tropical Africa	25	25	27	34	40	47	25	25	26	27	25	27
Middle East	38	40	46	56	71	78	38	39	43	42	46	48
Southern Asia	26	25	26	27	29	29	26	25	26	24	20	20
SELF-SUFFICIENCY-RATIO CONSUMABLE PROTEIN												
Developed countries	96	92	97	107	110	109	96	93	98	98	100	100
North America	142	142	149	174	175	176	142	144	152	148	147	145
European Community	59	60	67	74	81	82	59	60	67	70	74	77
Developing countries	106	102	104	93	93	91	106	103	105	100	99	100
Latin America	123	113	110	103	100	97	123	114	117	127	140	155
Tropical Africa	111	104	102	98	93	88	111	106	105	88	96	88
Middle East	87	85	88	58	65	71	87	81	86	77	85	79
Southern Asia	100	101	108	95	97	95	100	101	103	94	75	70
PRICE INDICATOR WORLD FOOD MARKET (DFP; 1965 = 0)*	-8	60	431	301	422	442	-8	43	60	18	13	17
WORLD HUNGER												
Total food deficit (10^8 kg cons. prot.)	15	29	40	43	62	97	15	29	25	50	124	141
Million people below minimum food standard	180	350	480	520	740	1160	180	350	300	600	1490	1690

Source: Hans Linnemann, et al, MOIRA: Model of International Relations in Agriculture, North Holland, Amsterdam, 1979, pp. 306 and 318.

Note *: DFP is 1965 dollars per 100 kg. consumable protein. DFP = 0 indicates a price equal to the base year. For example, DFP in 1965 was about \$100/ton, so DFP_t = 200 means a price of \$300/ton of consumable protein in year t, a threefold increase over the 1965 level (Linnemann, et al, p. 288).

generated by the model is apparently extremely sensitive to the growth rate assumption. The underlying cause of this sensitivity is not identified.

The scenarios generated with MOIRA and with the GOL model in the Global 2000 Report provide the only available projections of world food prices developed from formal models. These projections, in general, anticipate an upward trend in real food prices, but results from these sectoral models are highly sensitive to the economic growth rates taken as exogenous. Comparison problems are compounded by the choice of different base years for price indices and different definitions of food, but the sensitivity of prices to growth assumptions is clear. From Table 7, we see that the "High Income Growth" scenario of MOIRA projects food prices in 2000 at over three times the level of 1965. The Moderate Growth scenario actually anticipates a decline in food prices. While the GOL model under scenarios I, II and III doesn't foresee falling food prices, the high growth, tight supply scenario III projects world cereals prices in 2000 as 2.15 times the 1969-71 level. The trend scenario projects a price level of 1.45-1.95 times the base, and the low-growth scenario II foresees a 30 percent increase in price by 2000.

5. Discussion

In searching for a rationale for differences among projected magnitudes of LDC food deficits, a starting point would be a comparison of population and GDP growth rates and income elasticities. Surprisingly, U.N. medium variant population growth predictions and trend growth in GDP are used almost exclusively for basic scenarios. Income elasticity assumptions are not often published in these studies, and even if they were, most elasticities are at a national level and comparison across studies of the implications of particular elasticity assumptions would be complex. With reference to the trend projection models, however, some important observations can be made.

The Iowa State projections are the earliest set and cover the smallest number of countries, yet the deficits predicted are larger than the FAO version by a factor of 2. Among the FAO and IFPRI projections, the FAO's trend scenario seems closest, in terms of underlying assumptions, to the IFPRI high growth version. The FAO projected deficit for 1990 under the Trend scenario is 30% less than the IFPRI high growth scenario. Recall that the FAO work was published in 1981 and the IFPRI paper was released in 1977.

Turning to the Global 2000 Report, based on a model which allowed production and consumption to adjust to market change price levels, we see that the predicted deficits do not differ substantially from the levels actually experienced in 1978-1981. Of course, the perplexing features of these predictions is the associated increase in the real price of food.

In the main, all of the projections compared in this paper anticipate a profound break with the experience of recent decades with regard to the performance of the world food system. Rising real food prices or declining adequacy of food supplies in LDC's or both are foreshadowed, as is demand growth in excess of output growth. Recently, Brown (Brown, 1982) has popularized this view, although the arguments he advances have been frequently voiced by others since 1972/73. Also, material published in the early 1980's suggests that at that time, the USDA viewed the era of chronic surplus in agricultural markets as over (O'Brien, 1981).

As one surveys the literature from the "food pessimism" school, one finds recurrent rationales for this projection. On the supply side, curtailed output growth is attributed to loss in productivity of the land base, rising real input prices, limits to the amount of arable land not yet under cultivation and occasionally to the idea that innovation in agricultural science is slowing and the rate of productivity growth is declining. On the demand side, accelerated growth is anticipated as a large share of the

world's population enters a level of per income per caput where income elasticities of demand for food products is relatively high and where economic growth is rapid. In the models reviewed in this paper, however, these factors often are not formally incorporated into the analytical framework, so the link between these developments and the projections is not clear.

Also, this reasoning seems to beg another important question. That is, why should this break from trend happen now? Nearly all of the processes acting on the world food system cited above have been operating for some time, with the exception of price shocks to petroleum based inputs. What has happened during the 1970's that has made these constraints suddenly binding?

Earlier, we argued that price movements in agricultural commodity markets and the level of production and stocks of key traded commodities observed in the late 1970's and early 1980's tend to undermine the pessimism embodied in the projections compared in this paper. When viewed in a longer term context, the crises of 1973/74 appears less severe today than it did at the time. Why is it then, that all of the studies reviewed above were dominated by what now appears to be excessive pessimism regarding the balance between food production and utilization? We propose four reasons.

First, these models attribute the price movement in primary commodities of 1973-74 largely to supply side factors. Recently, however, Bosworth and Lawrence (Bosworth and Lawrence, 1982) have identified important demand side shocks. They point to several developments in the world monetary system that may have had substantial asset demand effects on commodity markets. The early 1970's witnessed the collapse of the Bretton-Woods agreement, including a substantial devaluation of the U.S. dollar and the suspension of gold convertability by the United States. At the same time, world liquidity was expanding dramatically. Bosworth and Lawrence estimate that

world reserves grew by over 22% per annum between 1969 and 1974, compared to a growth rate of about 3% per annum for the preceeding decade. At the same time, the OECD economies were pursuing strongly expansionary policies, generating economic growth rates in the neighborhood of 9% per annum in late 1972 and early 1973. Furthermore, wage and price controls in place at the time in the OECD countries largely excluded primary commodities. This confluence of factors certainly had the potential to deliver a strong demand side boost to commodity prices. Interpreting the resulting price movements as primarily supply side in origin leads to a critical distortion of reality.

Second, projection attempts to date have not encompassed the possibility of policy changes in response to price movements and increased scarcity.[4/] Christensen and Wituchi (Christensen and Wituchi, 1982) discuss recent shifts in food policies among food deficit African LDC's. While they caution against attaching undue significance to these developments prematurely, the increased incentives for agricultural sectors that are reported foreshadow a profound re-orientation of agricultural policy in the region.

Thirdly, in the case of statistically based projection exercises, the period from which data was collected for estimation was exceptionally stable (see Tables 3 and 4). It is to be expected that the turbulent 70's, following two decades of relative price stability, would introduce substantial "noise" into the system and drastically inflate the standard errors of extrapolation.

Finally, it should be recalled that the concern about the future balance between world food production and consumption arose during a period of widespread loss of confidence about the efficacy of technical progress as an instrument of human progress (Shils, 1974; Norden, 1979). Technical advance was viewed as an assault on the integrity of natural environments and as subversive of traditional institutions. The theme that "progress breeds not welfare but catastrophe" emerged from the underworld of social thought to become a serious theme in scientific and philosophical inquiry.

In concluding we would like to raise a methodological issue that emerges from our review of recent attempts to assess global food futures. The issue is the capacity of the analysts who construct and interpret futures models to insulate themselves from the short-run trends and events that dominate the intellectual and policy environment at the time the assessments are being made. There are large numbers of subjective judgements that enter into the construction of both the "trend" and the "analytical" models and in the use of the models to simulate alternative futures. It seems quite clear that the food futures simulations that we have reviewed in this paper were strongly influenced by the pervasive climate of "food pessimism" and more broadly, of "technological pessimism" that dominated much of the decade of the 1970's. It seems quite clear that the model builders and futures simulators were influenced by an intellectual environment that would have regarded more optimistic projections as "out of touch with reality."

It is not unreasonable to anticipate a new wave of long-term food projections to emerge during the next several years that will reflect current concerns about depressed commodity markets and the new "high-tech" optimism that has emerged during the early 1980's. When these new projections emerge it will be well to keep in mind that the fundamental factors that determine long-run trends in food production and demand - resource and cultural endowments and technical and institutional innovation - change much more slowly than suggested by recent cycles of optimism and pessimism about the anticipated balance between growth in food production and demand.

Footnotes

1/ Food availability in Sub-Saharan African LDC's continues to be an acute problem. For recent discussion, see Christensen (1981), Eicher (1982) and Christensen and Witucki (1982).

2/ A considerable body of literature has emerged on the economics of the steady state. See Daly (1977, 1980) and Knorr (1982).

3/ For a less critical viewpoint on this particular issue, see Day and Koenig (1975).

4/ King (1983) has recently discussed the adaptability of socio-economic and political systems as a problem in long-term projection studies.

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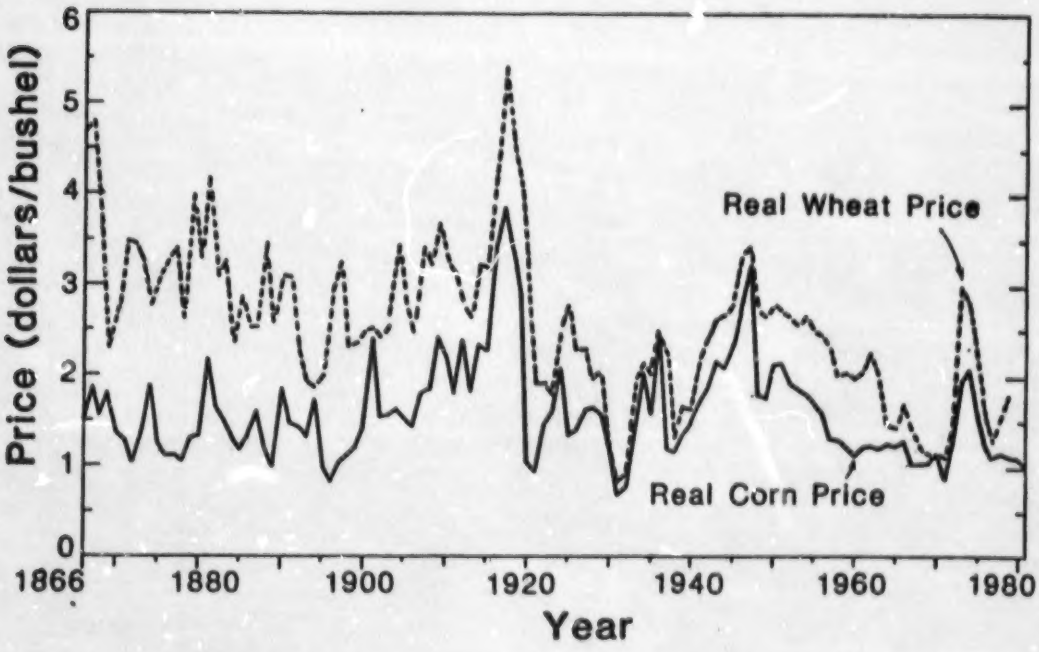
APPENDIX

Figure A-1. Real Prices of Wheat and Corn, 1866-1981, United States.

Tables A1, A2. Data on Total Food Production and Food Production Per Caput, 1951-1981.

Figure A-1. Real Prices of Wheat and Corn, 1866-1981, United States.



Source: Martin and Brokken (1982).

Table A1

Indices of Food Production - 1951-1981
(1969-70 = 100)

Country/Region	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
United States	65	67	69	70	73	75	76	79	80	82	82	82	86	86	90
Canada	73	81	78	63	75	80	69	74	74	78	67	84	91	86	95
Japan	70	78	68	72	91	87	89	91	96	100	100	102	97	100	100
Republic of South Africa	53	48	55	60	60	62	66	62	65	68	75	76	82	75	74
Oceania	51	58	60	61	64	63	61	72	69	71	73	81	83	88	82
Western Europe	62	63	67	70	70	72	72	75	76	81	80	85	87	87	89
Developed World	64	66	68	69	73	75	75	78	79	83	82	86	88	88	90
South and Central America	52	54	56	58	60	63	64	68	67	68	72	74	77	80	84
East Asia (Ex Japan)[a]	50	50	58	61	61	62	63	68	69	71	73	77	78	85	94
South Asia[b]	57	59	65	65	66	68	68	71	74	77	80	80	82	84	80
West Asia (Middle East)[c]	52	59	65	63	63	70	71	75	76	74	77	80	83	94	86
Africa (Ex Rep. Sc. Africa)	63	64	66	68	68	71	71	74	76	80	77	82	84	85	87
Developing World	56	58	63	64	64	67	68	71	72	75	77	79	81	84	84
USSR	43	48	49	51	56	64	63	71	71	72	74	76	71	82	81
Eastern Europe	64	60	65	65	69	69	77	75	80	82	81	79	93	86	88
China[3]	--	66	67	68	73	75	78	87	71	60	62	70	76	83	88
Centrally Planned[d]	50	52	55	56	61	66	68	72	74	76	76	77	76	84	83
World[d]	58	60	63	64	67	70	71	74	76	78	79	81	83	85	86

Source: 1. World Indices of Agricultural and Food Production, USDA, ERS, Statistical Bulletin #669, July 1981.
2. World Indices of Agricultural and Food Production, 1972-81, USDA, ERS, Statistical Bulletin #689, August 1982.
3. Authors' calculations based on data in, Anthony M. Tang and Bruce Stone, Food Production in the People's Republic of China, Research Report 15, International Food Policy Research Institute, May 1980. Series measures Gross Value of Agricultural Output.

Notes:
a Burma, Indonesia, Republic of Korea, West Malaysia, Philippines, Taiwan, Thailand.
b Afghanistan, Bangladesh, Sri Lanka, India, Pakistan.
c Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey.
d Excludes People's Republic of China.

Table A1 (continued)

Country/Region	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
United States	91	96	97	98	96	105	104	106	102	111	113	118	120	125	121	132
Canada	105	91	98	100	92	107	101	102	94	106	117	119	122	118	121	130
Japan	102	110	112	107	100	92	99	99	99	103	97	106	105	105	94	95
Republic of South Africa	80	107	89	94	95	111	119	97	126	117	118	127	131	127	133	150
Oceania	93	86	101	98	98	104	103	106	107	117	121	120	130	120	112	117
Western Europe	90	96	98	97	100	103	102	107	111	109	107	109	116	118	124	120
Developed World	92	97	99	99	98	103	103	105	106	109	109	113	117	120	119	122
South and Central America	86	91	92	96	102	102	102	108	113	119	125	129	134	138	143	149
East Asia (Ex Japan)[a]	89	87	91	97	101	103	101	110	114	123	131	135	145	146	148	157
South Asia[b]	79	87	93	97	102	101	97	106	101	113	111	119	124	118	121	129
West Asia (Middle East)[c]	90	96	99	98	100	103	110	104	116	124	136	135	142	140	145	144
Africa (Ex Rep. So. Africa)	86	88	91	98	99	102	104	102	107	110	112	110	115	115	118	120
Developing World	84	89	93	97	101	102	102	106	108	116	119	123	129	128	131	136
USSR	91	93	99	95	102	103	99	117	111	103	115	114	123	114	111	108
Eastern Europe	95	98	100	99	97	104	111	115	120	117	121	122	127	125	122	124
China[3]	94	100	93	95	105	107	112	118	122	124	124	124	--	--	--	--
Centrally Planned[d]	92	95	99	96	100	103	103	116	114	108	117	117	125	118	115	114
World[d]	90	94	97	97	100	103	102	108	108	111	114	117	122	121	121	124

Table A2

Indices of Food Production per caput, 1951-1981
(1969-71 = 100)

Country/Region	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
United States	85	88	89	89	90	91	90	92	92	93	92	96	93	92	95
Canada	111	119	112	88	102	105	89	93	90	92	78	97	103	95	103
Japan	87	94	81	85	106	100	102	103	107	111	110	111	105	106	105
Republic of South Africa	87	77	86	91	89	89	93	86	87	89	95	95	99	89	85
Oceania	76	84	85	85	87	84	79	92	85	86	87	94	95	98	90
Western Europe	72	73	77	79	78	81	80	82	83	88	86	90	91	91	92
Developed World	79	81	82	83	86	87	86	89	89	92	91	93	94	93	95
South and Central America	87	89	89	91	90	93	92	94	90	89	92	93	94	94	97
East Asia (Ex Japan)[a]	78	77	87	89	88	87	86	92	90	91	91	94	93	98	95
South Asia[b]	83	85	92	91	90	91	90	92	94	96	98	95	96	96	90
West Asia (Middle East)[c]	87	96	102	97	95	103	102	104	102	96	98	100	101	98	98
Africa (Ex Rep. So. Africa)	101	100	101	102	100	102	100	101	102	103	98	102	102	100	100
Developing World	86	88	93	93	92	94	93	95	95	95	96	96	97	97	95
USSR	56	62	63	64	69	78	75	83	81	82	82	83	77	88	85
Eastern Europe	74	69	75	73	77	77	84	81	86	88	86	83	87	90	91
China[3]	--	97	96	95	100	100	102	111	88	73	75	82	88	94	98
Centrally Planned[d]	64	65	68	68	73	78	79	83	83	84	84	83	81	88	87
World (Ex P. R. China)[d]	82	84	86	86	89	91	90	93	93	95	94	94	94	96	95

Source: 1. World Indices of Agricultural and Food Production, USDA, ERS, Statistical Bulletin #669, July 1981.
2. World Indices of Agricultural and Food Production, 1972-81, USDA, ERS, Statistical Bulletin #689, August 1982.
3. Authors' calculations based on data in, Anthony M. Tang and Bruce Stone, Food Production in the People's Republic of China, Research Report 15, International Food Policy Research Institute, May 1980. Series measures Gross Value of Agricultural Output Per Caput.

Notes:
a Burma, Indonesia, Republic of Korea, West Malaysia, Philippines, Taiwan, Thailand.
b Afghanistan, Bangladesh, Sri Lanka, India, Pakistan.
c Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey.
d Excludes People's Republic of China.

Table A2 (continued)

Country/Region	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
United States	95	99	99	99	96	104	102	103	98	106	108	111	112	116	112	121
Canada	111	95	101	102	92	106	99	98	89	99	108	109	110	106	107	114
Japan	106	113	115	108	101	91	96	95	94	97	90	98	95	94	84	84
Republic of South Africa	89	115	94	96	95	109	113	90	113	103	101	107	108	101	103	113
Oceania	99	91	105	100	98	102	99	101	100	108	109	107	114	105	96	99
Western Europe	92	98	99	98	100	103	101	105	108	105	103	105	111	114	119	115
Developed World	96	100	101	100	98	102	101	102	102	104	104	107	110	111	110	112
South and Central America	96	98	97	98	102	100	97	100	102	105	108	108	110	110	112	114
East Asia (Ex Japan)[a]	98	93	96	99	101	100	97	102	104	110	115	116	122	120	119	124
South Asia[b]	87	93	97	99	102	99	93	100	93	101	97	103	104	97	97	101
West Asia (Middle East)[c]	100	104	105	100	100	100	104	96	104	109	116	111	114	110	111	107
Africa (Ex Rep. So. Africa)	96	96	96	101	99	100	98	94	96	96	95	90	92	90	89	88
Developing World	93	96	97	100	101	100	97	99	98	103	103	104	107	103	103	105
USSR	95	96	100	95	102	102	97	114	107	98	109	107	115	105	101	98
Eastern Europe	97	100	102	100	97	104	110	112	117	113	116	116	120	107	114	115
China[3]	102	106	96	96	103	103	106	109	110	111	109	106	--	--	--	--
Centrally Planned[d]	96	97	101	97	100	103	101	113	110	104	111	110	117	110	106	104
World (Ex P. R. China)[d]	97	99	101	99	100	101	99	102	101	101	102	103	106	103	102	102